Experimental Security Panoramas Workshop

DARPA Initiatives in the Cyber Experimentation Domain

National Cyber Range (NCR)

Lt Col David Robinson, PhD

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Mr. Don Woodbury
Director, STO
703-696-2362
donald.woodbury@darpa.mil

Strategic Technology Office

Dr. Brent Appleby
Deputy Director, STO
703-248-1531
brent.appleby@darpa.mil

Dr. Larry Stotts
Deputy Director, STO
571-218-4346
larry.stotts@darpa.mil

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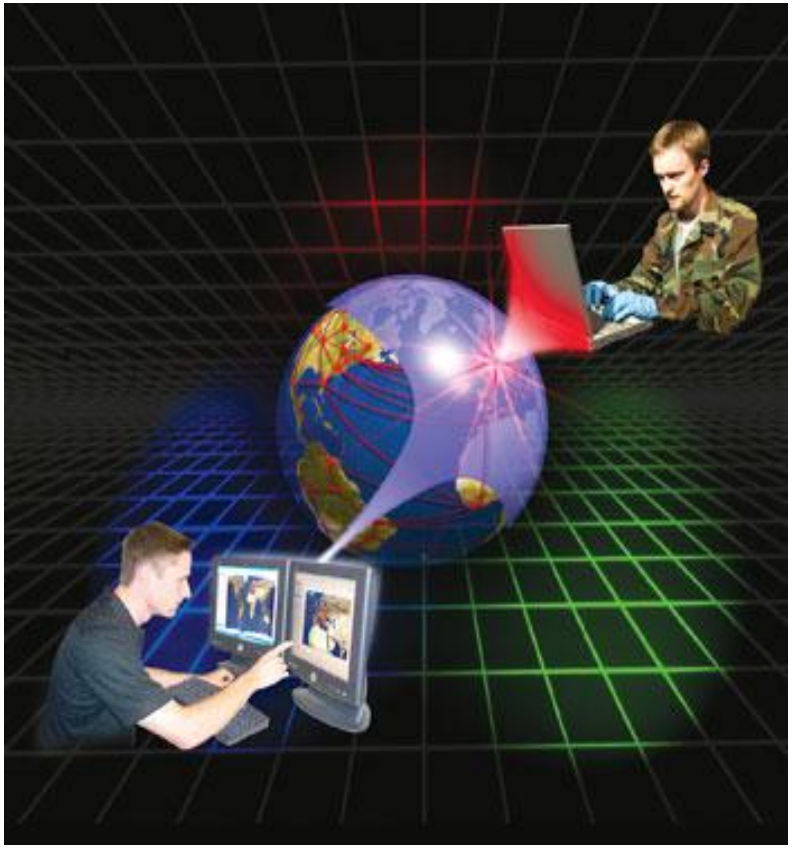
Cyber Threat Summary

- **Loss of military technological advantages:** The continued exploitation of information networks and the compromise of sensitive/classified data needs to be addressed to ensure the United States military's technological advantage.
- **Loss of U.S. economic value:** Losses from intellectual property due to data theft in 2008 are estimated at $1 trillion.
- **Failure of critical infrastructures:** The intelligence community has concluded that a number of nations already have the technical capability to disrupt telecommunications, electrical power, energy pipelines, refineries, financial networks, and other critical infrastructures.
- **Exploitation of global financial services:** Data breach of a U.S. retailer resulted in the loss of personally identifiable information affecting 45 million credit and debit cards.



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National Cyber Range Program Overview

Background:

- Comprehensive National Cybersecurity Initiative (NSPD-54)
  - "To establish a front line of defense against today's immediate threats by **creating or enhancing…the ability to act quickly** to reduce our current vulnerabilities and prevent intrusions."
  - To "develop **enduring 'leap-ahead' technology**…that provide[s] increases in cybersecurity by orders of magnitude above current systems and which can be deployed within 5 to 10 years." (Initiative 9).

NCR Program Goals: Develop the technologies (NOT just another range) for advanced cyber research and testing

- Hardware and software automation tools that allow a range to be rapidly configured to emulate complex, large-scale heterogeneous networks
- Software tools and sensors that allow cyber threats (e.g. worm or virus) to be thoroughly studied, providing a fundamental understanding of their behavior and potential defense mechanisms
- Decrease the time required to sanitize and reconfigure the range after testing to decrease downtime between tests
- Enable multiple, independent, simultaneous, multi-security level experiments, from TS/SCI to unclassified, on the same infrastructure to maximize the range utilization
- Simplify the process of introducing and testing new code on a cyber range

The National Cyber Range seeks to enable experimentation to address the growing cyber threat in a manner that is more thorough, quicker, and cost effective than existing ranges.

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National Cyber Range Objectives and Challenges

Enable leap-ahead technologies through:

- Development of revolutionary cyber-security experimentation technologies
- Development of revolutionary automated range configuration technologies
- Development of innovative experimentation-specific technologies
- Delivery of technologies to existing and future ranges and communities

Challenges

- Develop technologies that currently do not exist
- Scale experiments and technologies
- Replicate desired systems within physical and time constraints

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NCR Technical Approach

Automated Range Management

- Multiple, independent, simultaneous experiments
- Simultaneous Unclassified to Top Secret/Special Compartmentalized Experiments

Automated Experiment Management

- Design, configure, monitor, analyze, and release experiments with interactive experiment suite
- Experiment toolkit/repository for reuse of recipes and architectures

Node Replication

- Rapidly generate and integrate replications of new machines
- Forensic data collection across range without impacting experiments
- Sanitize machines within minutes rather than hours

Research Focused

- Implements a scientific method for rigorous cyber experimentation
- Easily integrate revolutionary research systems
- Connect securely to existing special purpose ranges
- Realistic experiments of Internet/Global Information Grid scale research
- Rapidly integrate new research protocols across the protocol stack

Human Interaction and Replication

- Realistically replicate adaptive human network behavior

Security Requirements

- Encapsulate and isolate experiments, data storage, and networks
- Unclassified to TS/SCI/SAP

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NCR Technologies

Cyber Foundation	Range Management	Experiment Management
• Cyber Scientific Method • Cyber Scientific Experiment Language Specification—schema used to capture every aspect of an experiment • Asset Characterization • Asset Description Specification and Database Specifications • Security Management Design • Experiment Design using Statistical Methods • Network Configuration Design Input • Leverage of additional protocols, services and networks	• Knowledge Management Suite • Facility Management Suite • Experiment Specification Tools • Automated Pre-Experiment Planning • Automated Resource Allocation --- • Rapid and Secure Resource De-obligation after Experiments • Efficient Free Resource Pooling • Lessons Learned Knowledge Management Suite • Incorporation of Additional Technologies into the Range • Sanitization Toolset	• Automated Range Configuration, Validation and Experiment Close-Out • Development of Instrumentation for Data Collection • Automated Experiment Control and Management • Automated Data Analysis and Presentation Tools • Recall of Previous Experiments, Results and Data Analysis • Semi-Automated Library of Offensive and Defensive Tools • Automated Reconstitution of Experiments • Real Time Human Interaction (Real and Simulated) with Experiments

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NCR Two Performers – Two Designs – Some Commonality

OnPath Layer One Network Switch

- Electronic Patch Panel
- Tested By Sandia National Labs
- All network assets can be quickly reconfigured to meet follow-on requirements

Data At Rest - Encryption Is The Key

- Performers are using Suite B NSA Encryption Technologies
- Data at rest is Encrypted and Considered Cyphertext
- Hard Drives Never Have Classified Data On Board
- No Traditional Destruction Required
  - Drives will still be destroyed as classified at end of life

Sanitization

- Server Sanitization
  - Both performers have well engineered sanitization plans
    - Sanitizing **ALL** Memory "as required" during experiments
    - **ALL** memory will be sanitized at the end of experiments
  - Both performers have worked closely with vendors for highly detailed statements of volatility.

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NCR Hardware and Current Status

Two performers are developing range prototypes:

- Lockheed Martin
  - 220 node range, able to emulate > 2000 users
- John Hopkins Applied Physics Laboratory
  - 50 node range, able to emulate > 500 users

Common system features

- Layer-1 network switch
  - Electronic patch panel for rapid and automated range configuration and reset
- Encrypted data at rest
  - Data at rest is encrypted and considered cyphertext (Suite B NSA encryption technologies)
  - Hard drives never contain classified data
  - No traditional sanitization or destruction of magnetic media required
- Range sanitization
  - All memory, including non-volatile memory, sanitized at the end of experiments
  - Hard-drive sanitized by clearing encryption keys

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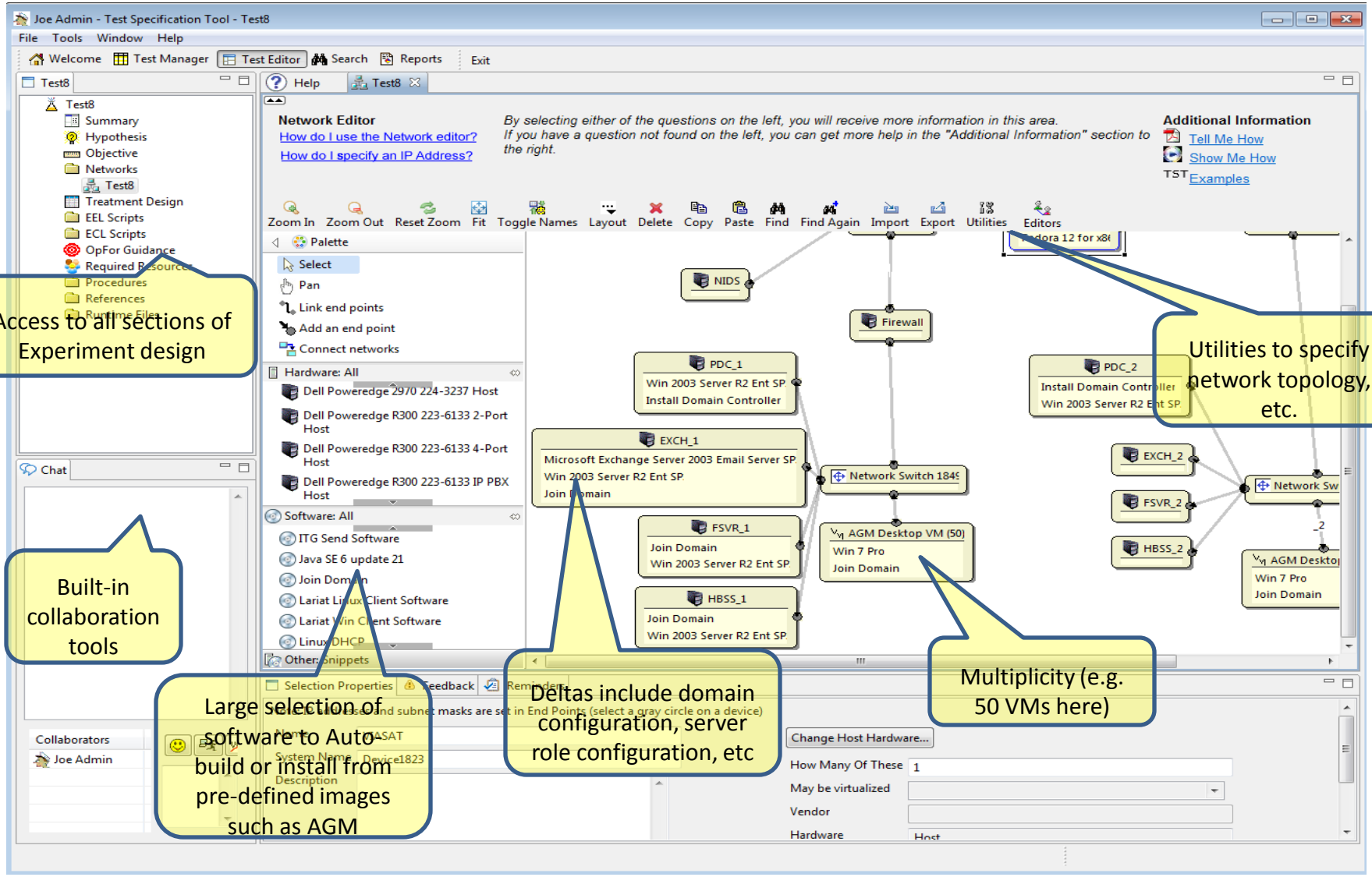
Lockheed Martin Test Specification Tool



Drag and Drop experiment design with interface similar to Microsoft Visio.

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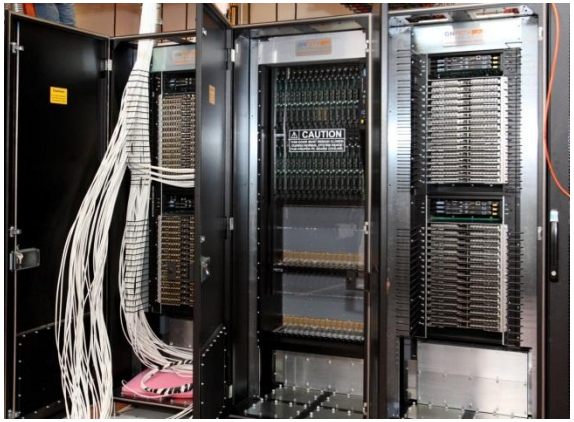
NCR Significant Accomplishments

- **Development of Two Operational Prototypes**
  - Johns Hopkins University Applied Physics Laboratory (JHU/APL
    - Operating Procedures 100% complete
    - 100 % of hardware integrated
    - 4 million Software Lines of Code integrated
    - Integration Testing 85% complete
    - SCI Facility is 100% complete—still requires equipment move
    - Interactive Test Suites 100% complete
  - Lockheed Martin (LM) NCR Range
    - Operating Procedures 100% complete
    - 100 % of hardware integrated
    - 5 million Software Lines of Code integrated
    - Integration Testing 90% complete
    - SCI Facility is 100% complete—no equipment move required
    - Interactive Test Suites 100% Complete
  - Certification and Accreditation (C&A) to operate from Unclassified to Top Secret levels
    - Documentation 90% complete
    - C&A Component and End-to-End Testing 100% complete

- **Development of Key Technologies**
  - Automatic experiment planning/design 95% complete
  - Automatic creation of new node configurations 90% complete
  - Automated range configuration/validation 100% complete
  - Controlled Interfaces are 100% complete
  - Automated sanitization 90% complete
  - Virtual machine development 90% complete
  - Time Synchronization capability 100% complete
  - High fidelity traffic generation 90% complete
  - Experiment Control is 100% complete
  - Data Analysis System is 80% complete
  - Visualization of experiment results is 90% complete

Layer-1 Switch Front



Layer-1 Switch Back

Layer-1 Switch, enabling automated range configuration, has completed physical integration, software control development and initial testing.

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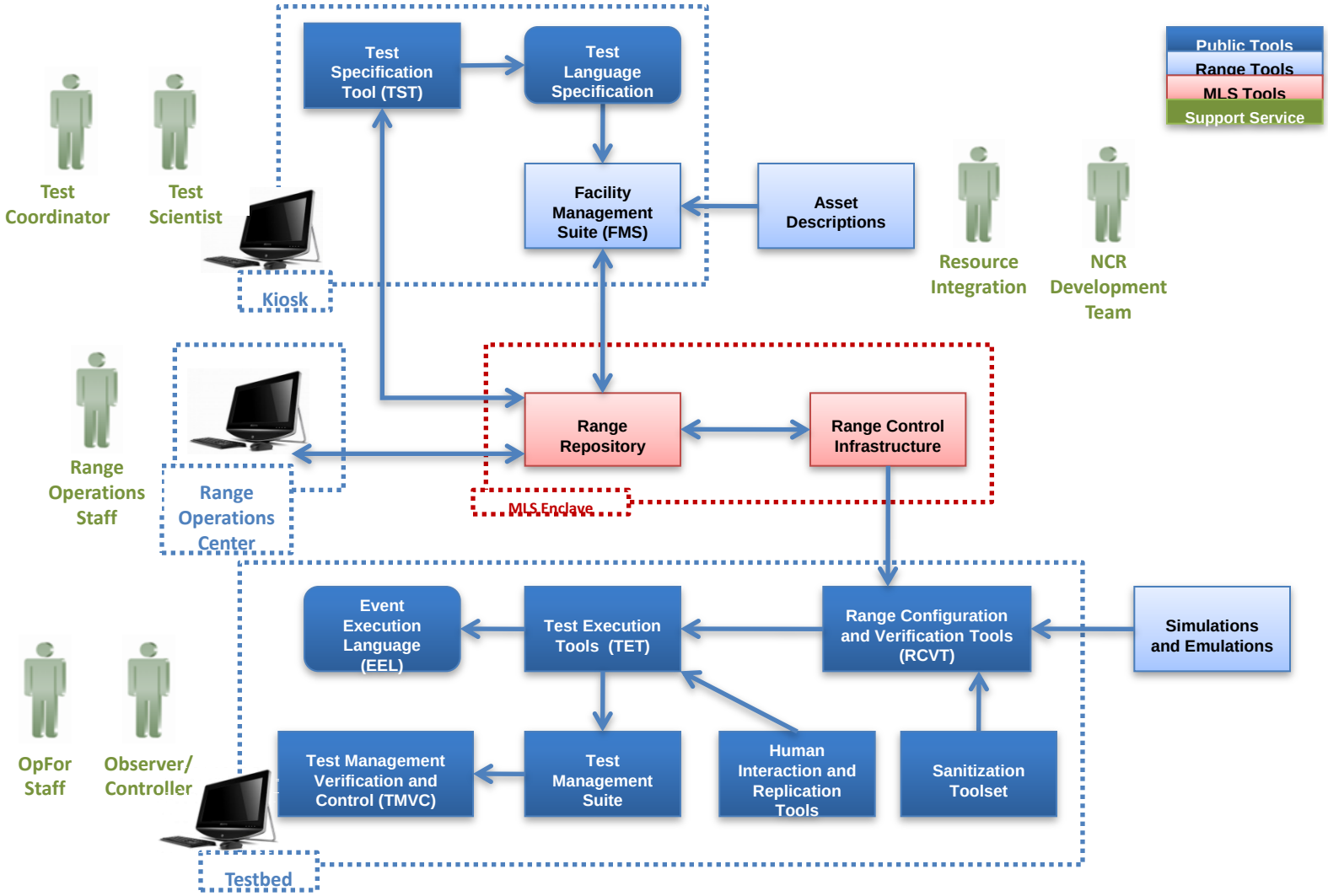
NCR Overview – Logical Architecture



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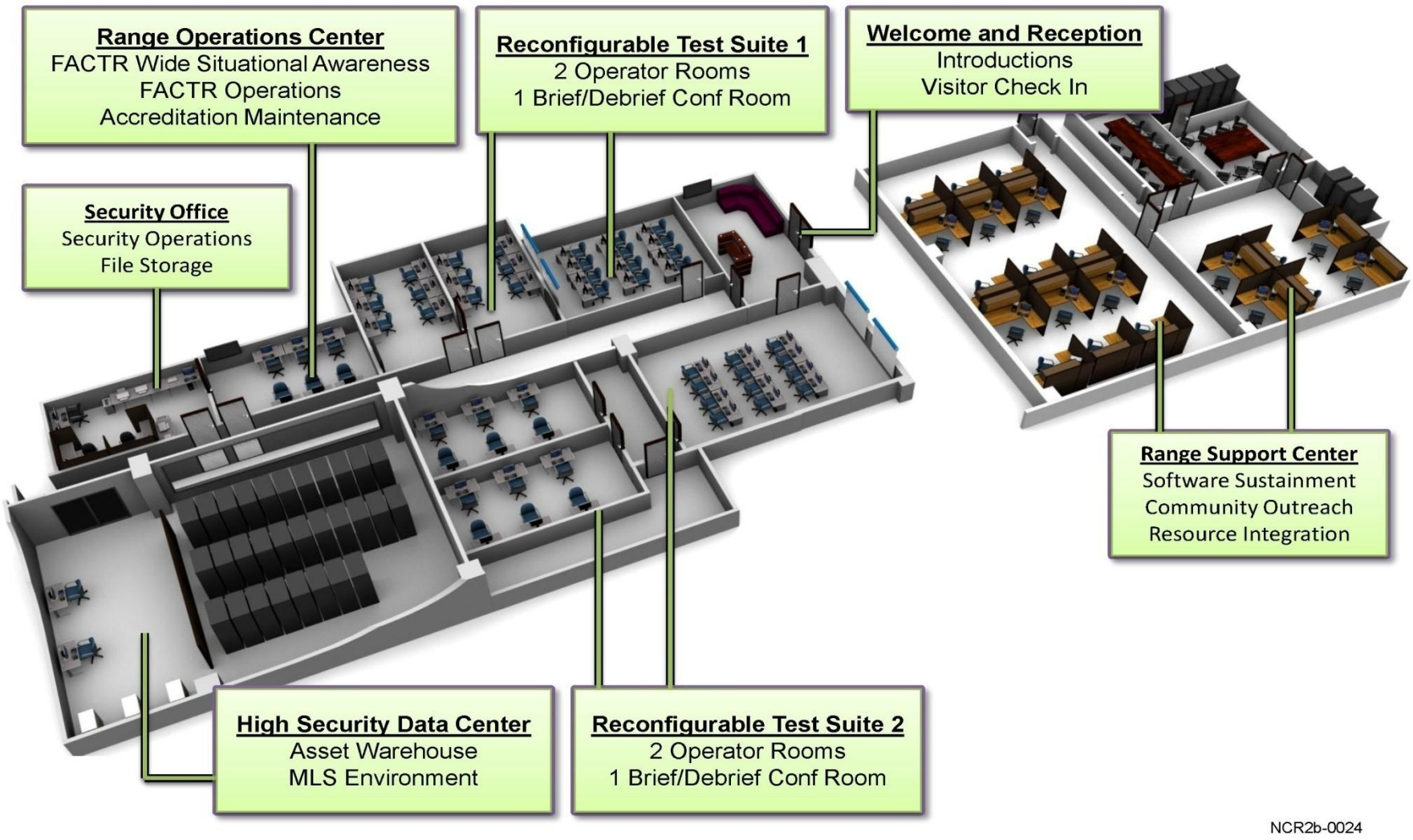
Prototype NCR facility



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NCR Use Case Examples and Capabilities

- Advanced cyber research and new capability development
- Testing of network protocols, policies, and vulnerabilities
- Analysis of malware collected targeting national interests
- Providing simulated and emulated environments for mission critical software upgrades on national assets
- Source selection testing for network hardware and software procurements
- Cyber training and exercises
- Secure cloud computing and storage architecture

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NCR Use Case Examples and Capabilities

- Testing New Offensive and Defensive Cyber Technologies
  - NCR provides the ability to rapidly design and conduct tests with realistic network topologies and software configurations
  - Malicious new code can be introduced onto the range without fear of compromising range security

- Testing New and Advanced Network Protocols
  - Ability to scale range size to > 2000 users to emulate large enclaves
  - The NCR can emulate test networks with network nodes (workstations and servers) in linear, mesh, star, or custom network topologies
  - The range supports a diverse set of Linux and Window's based operating systems, patch levels, and configurations. The NCR tools provide the ability to build new host configurations on the fly
  - NCR's diverse traffic generation systems can provide required traffic for testing:
    - High data rate legacy (e.g., HTTP, SMTP, FTP, etc.) traffic
    - Malicious background traffic and automated port scanning and attack traffic

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NCR Use Case Examples and Capabilities

- Malware Analysis
  - Testing for analysis of malware collected by various DoD response teams, the Joint Malware Catalog, and US-CERT (all currently conducts small scale testing)
  - Precise specification of OS, patches, and application software on target system
  - High test replication fidelity through full coordinated scripting and automation tools
  - Pause, resume, and rapid restore functionality allow for iterative testing
  - High fidelity sensors and a full measurement framework for adding new sensors

- Simulation Environment for National Asset Command and Control
  - Test mission critical software upgrades and security profiles on simulations of national assets which cannot actually be taken off-line

- Enterprise-wide Solutions Steering Group (ESSG) RFP Source Selection Testing
  - The ESSG procures DoD wide licenses for anti-virus, HBSS, firewalls, and similar products. Reduced test design and testbed build times allow for more testing on each potential solution
  - Use of pre-configured standard images on the NCR (USN COMPOSE, Army Gold Master, USAF Standard Desktop) allow for more DoD relevant test results.
  - Vetting procurements on the NCE would allow for services, CoComs, and other interested parties to observe and participate as required

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NCR Use Case Examples and Capabilities

- Training and Exercises
  - The NCR is capable of hosting:
    - Defensive exercises like CDX (USMA, USNA, USAFA, AFIT, NPS annual exercise)
    - Offensive training such as cyber capture the flag exercises for war fighters
  - The NCR provides advanced measurement and visualization tools for cyber event coordinators
  - A full compliment of sensor suite are available that allow for both simple and complex metrics and measures of participant performance without interfering with their workflow
  - The diverse set of advanced traffic generation tools on the NCR can be used to provide cover for red teams
  - NCR provides the ability to pause operation and to rapidly revert to a check point, allowing for immediate feedback to reinforce lessons learned and repeat failed events

- Secure cloud computing and storage architecture
  - The NCR architecture represents a MLS cloud computing and storage facility. The range tools can be used in future cloud architectures as well as cloud security testing

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NCR Program Schedule

- Phase I (Q2 2009 – Q4 2009)
  - Develop initial design and concept of operation
- Phase II (Q2 2010—Q4 2011)
  - Complete the design and demonstrate range technologies
  - Modified in November 2010 to complete an operational prototype
    - Independently verify and validate range technologies
    - Certify and accredit range to operate at multiple security levels (DNI)
- Phase II-B (Q4 2011—Q4 2012)
  - Operation/testing of the prototype NCR
  - Enhance existing software tools and ensure the range hardware and software are stable to allow for a seamless transition
  - Develop business model for sustainable range operation and expansion beyond FY12
  - Transition the range and associated technologies

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NCR Phase II-B Objectives and Approach

Phase II-B: DARPA will operate the NCR during Phase II-B (12 month) beginning in Fall 2011. DARPA and the NCR Management Transition Partner will work together to demonstrate the technologies developed during Phase II and to conduct real experiments.

Phase II-B Objectives:

- Establish and execute a portfolio of experiments and range use cases
- Demonstrate the advanced technologies developed in Phase II to the cyber community
- Develop business models for sustainable range operation and expansion beyond FY12

Phase II-B Prototype Operation Approach:

- Refine Prototype operation to minimize time required to execute experiments
- Correct any software/hardware issues that prevent Prototype operation and transition
- Establish and execute a portfolio of experiments supporting cyber development that other agencies can leverage in the cyber experiments
- Complete (if not accomplished in Phase II) and maintain Certification and Accreditation of the Prototype
- Document experiment/demonstration results including significant NCR unique successes and significant Prototype shortcomings
- Transition NCR Prototype software tools to other existing ranges

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Summary

Challenge	Current Ranges	National Cyber Range (Planned)
Range Application	• Testing in a degraded environment and information assurance • Generalized behavior of cyber tools • Security often prevents the introduction of new code	• Develop new and untested capabilities • Ability to introduce and execute new code • Understand the fundamental behavior of new tools • Rapid reset and reuse of range to allow for multiple tests of simple thought experiments
Security	• Single test at single security level	• Multiple simultaneous experiments at different security levels
Rapid Testbed & Test Configuration	• Manual configuration of hardware and tests with scripts	• Automated configuration of hardware and experiments • Range design tool to design experiments, configure testbed resources, and manage testbed assets
Network and User Realism	• Tradeoff between physical (realism) and scale (emulation) • Statistical traffic generators	• Large-scale combinations of physical and virtual systems • Diverse device emulation • Traffic generators that more realistically emulate human behavior
Rapid Testbed Recovery	• Primarily single-use	• Automated range sanitization in order to support re-use of testbed assets

The NCR key features:

- **Automated range configuration to simulate diverse network profiles**
- **Automated range sanitization (hard-drives, NVRAM)**
- **Custom network performance sensors**
- **Ability to run multiple simultaneous experiments at different security levels**
- **Simplified ability to introduce, execute, and test new (malicious) code**